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INSECTS INVOLVED IN THE MORTALITY OF PINUS PONDEROSA VAR. SCOPULORUM

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U. S. DEPARTMENT OF AGRICULTURE
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INSECTS INVOLVED IN THE MORTALITY OF *PINUS PONDEROSA* VAR. *SCOPULORUM* AT THE INSTITUTE OF FOREST GENETICS

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Scopulorum pines have been growing in the Eddy Arboretum and in the progeny blocks of the Institute since 1929. Under the environmental conditions at Placerville this variety of ponderosa pine is characterized by very slow growth rate and by a high susceptibility to attack by certain insects. Compared with the other varieties of ponderosa pine which are being propagated here, the scopulorum strain seems to be the least vigorous of the lot. In the 1929 progeny block, scopulorum trees completed the first decade of growth without serious mortality, but since then so many trees have died that most of the anticipated value of this progeny test has been lost. Some studies have been made to determine the cause of this high death rate, and in 1947 control measures were undertaken to prevent further loss of trees.

This report is intended to put on record what is known of the entomological history of the scopulorum plantings, to appraise the role of insects in the death of the trees, and to summarize what has been accomplished to date by control work. The growth studies and mortality records, which have been kept by Robert Weidman, have made possible a complete and accurate record of what has transpired since the beginning of the progeny test. The writer's study of insect activity in the block was started in June 1946.

SEED SOURCES AND PLANTING DATA

The scopulorum trees in the progeny block come from widely distributed localities in Utah, Nevada, Colorado, Wyoming, Nebraska, South Dakota, Montana, and Arizona.

Date of nursery sowing 1929

Year of planting 1931

Total number of trees planted 363

Eight trees which died from planting failure were replanted in 1933.

MORTALITY RECORD TO JUNE 1948

Out of this total number of 363, trees designated as Pinus ponderosa variety scopulorum, 135 were from the Coconino National Forest and other localities in Arizona. These Arizona trees have shown practically no susceptibility to insect attack, and such mortality as they have suffered has been due to snow break and similar injury. Because of this apparent immunity the Arizona trees were not included in the spray control and fertilization experiments which were carried out in 1947. Excluding these Arizona trees, mortality data is presented in chronological order.

TABLE I

1931	Number of trees planted with seed sources in Utah, Nevada, Colorado, Wyoming, Nebraska, South Dakota, and Montana (referred to as "scopulorum trees" in this report)		178
1940-41	Removed because of resin midge injury	65	
1942	Died from attack by flathead and weevil	1	
1943	" " " " " " "	3	
1944	" " " " " " "	10	
1945	" " " " " " "	8	
1946	" " " " " " "	20	
1947	Died from topkilling and flathead attack	2	
	Removed because of snow break or unaccounted for	10	
	Total number of trees lost		119
	Trees still living, June 21, 1948		59

THE INSECTS INVOLVED IN DEATH OF SCOPULORUM TREES

1. The Resin Midge, Retinidiplosis sp.

In 1935 Mr. Austin called attention to resin midge injury which was then becoming prevalent in planted ponderosa pines in the arboretum and progeny blocks of the Institute. Observations in other areas indicated that this infestation was part of a general upsurge of resin midge activity which extended through the ponderosa pine belt of the Sierras and northern California. This outbreak lasted from about 1934 to 1939.

J. S. Tuill, of the Forest Insect Laboratory at Berkeley, spent some time during this period studying the biology of the resin midge, and worked out a protective spray formulae for its control. In 1940 the scopulorum progeny block, which had become badly infested by the midge, was sprayed, May 1 - 3. Tuill reported that, although this application was too late for optimum effectiveness, a mortality of 70 to 90 percent of resin midge larvae resulted from the spray. He also reported that the density of trees in the block was too great to obtain the best results by spray control.

By 1940 many of the trees had become badly deformed by resin midge injury and a thinning operation was decided upon to dispose of these undesirable trees and at the same time relieve the over crowded conditions in the block. During 1940-1941, 65 trees were removed. After this thinning operation the resin midge infestation subsided in the progeny block as it did elsewhere in most of the areas where it had been epidemic. It has not been a factor in the plantings of the Institute since then and at the present time is almost non-existent.

2. Infestations following the resin midge.

Elimination of the resin midge did not bring an end to insect problems in the scopulorum block. From 1942 through 1946 there was a steadily increasing loss of trees which died rather suddenly as though affected by a primary disease or insect enemy. The trouble could not be attributed to drought conditions as the annual precipitation was favorable throughout the period, and other strains of ponderosa pine made vigorous, normal growth, including the Arizona strain of scopulorum. The trouble was limited to the scopulorum trees coming from localities east of the Continental Divide and from Utah and Nevada.

It was not until 1946 that investigations were made to see if the mortality could be attributed to pathological causes, diseases, or insects. Dr. Willis Wagener, of the Office of Forest Pathology, examined some of the dying trees in the spring of 1946 and could find no evidence of disease or pathological conditions that would account for their condition. Dr. Wagener, however, called attention to their retarded growth rate and the presence of insects in the phloem and cambium areas.

In June 1946, the writer made an examination of both the currently dying trees and those which had died since 1942. He found that practically all of them had been attacked by two species of cambium feeding insects which attack living trees. These were the California pine flathead, Melanophila californica and the pine reproduction weevil, Cylindrocopturus eatoni. Although these two species were associated in their attacks upon these scopulorum trees, they are quite different in their habits and are not ordinarily found together in infested pines. This can be better understood if we briefly review their life histories.

a. The California pine flathead, Melanophila californica.

This buprestid is commonly found in overmature trees or in younger trees that have been weakened by drought, defoliation or other injury. Eggs are laid in bark crevices; the young larvae bore into the cambium layer where they make tiny mines in the live tissue. At first these mines are so small that they appear only as wavy brown lines in the living cambium, but gradually become larger as the larvae grow. As long as the tree remains alive it heals over these mines with scar tissue, which forms small ridges on the surface of the sapwood. This is known as the incipient growing stage. A larvae may live for one, two, or even three years in the same tree; but if the tree dies at any time, the larva leaves the cambium and enters the phloem and cortex, where it rapidly cuts a large irregular mine at the end of which it transforms to pupa and adult. Thus living trees may carry incipient flathead infestations over long periods. If the tree does not die, incipient larvae never reach the fast growing stage and finally die in the cambium. Infested trees which recover their growth vigor will throw off the attack entirely, leaving the incipient mines buried in the wood rings as small resinous scars.

It was evident in 1946 that practically all of the scopulorum trees except the Arizona variety were infested by incipient flathead larvae. This could not be positively determined in the living trees without cutting them, but their slow growth and sparse foliage were fairly indicative symptoms. (Figure 2) In the dead and dying trees which were cut and sectioned, scars in the wood rings indicated that these flathead attacks began about 1939-40, and had been continuing up to the present time. Most of the trees had resisted the flathead attacks for several years, but when they were also attacked by the weevil in the tops and limbs, they succumbed quickly and the flathead larvae quickly entered the phloem where they began cutting the large mines that characterize the fast growing stage.

b. The pine reproduction weevil, Cylindrocenturus eatoni.

This insect usually prefers young trees from 3 - 10 years old. To find it attacking these scopulorum trees which had passed their fifteenth year of growth and were 12 to 17 feet in height, was an unusual record. The weakened condition of the trees due to their slow growth and the incipient flathead mines may have made them especially attractive to the weevil.

The adults of the weevil come out in May and June and first feed on the needles by boring punctures through the epidermal tissue. Later they make similar punctures on the thin bark of the main stem and limbs. The larvae first mine the cortex and phloem, and as the tree weakens extend their mines down to the cambium and wood. Development takes place rapidly in susceptible trees which are usually killed by the end of summer.

In these macpulorum trees it was only the upper 6 or 7 feet of the top that was attacked and killed by the weevil; the flathead infestation was found in the lower part of the main stem. Nearly all trees which died had been top-killed by the weevil before the flathead infestation went into the fast growing stage. (Figures 3 and 4).

3. Composition of infestation in dying and dead trees.

Case history studies were made of 20 trees which died during the 1946 season and were subsequently cut and examined. In all of these the work of Cylindrocenturus was found in the top, and of Melanophila in the base and mid bole.

In addition, 6 trees which were killed in the top only (1 in 1945 and 7 in 1946) were examined by cutting out the top and tracing the infestation in the dead area. These were all found to have been attacked by Cylindrocenturus.

4. History of flathead attacks shown by growth rings.

Six trees which had died either in 1945 or 1946 were cross-sectioned and a study made of the scars of incipient flathead mines imbedded in the growth rings. These six trees were selected because they appeared to be typical of the growth behavior of scopulorum trees in the block and represented the general pattern of insect attack. A summary of data from these six trees is presented in table II. Photographs of sections from 2 typical trees are shown in Figures 5 and 6. All of this material bears out the conclusion that the pine flathead started working about 1940 and that growth of trees since then has been irregular; that the weevil began to be a factor about 1943; and that with the increase of weevil damage there was a corresponding increase in mortality of trees within the block.

CONTROL MEASURES

By the late summer of 1946 it was evident that an aggressive population of Cylindrocentarus was attacking many of the remaining trees in the block. Although most of the trees under attack still appeared to be alive in early September, numerous tiny pitch spots caused by weevil punctures on the upper internodes and branches indicated that a heavy attack was under way.

Table II. Data from Sectioned Trees.

Tree Number	D. B. H.	Height	Died	Melanophila californica	Cylindrocopturus eatoni
L55A-R38A	1.9"	9'	Fall of 1945	First incipient attack - 1941 fast growing stage - fall of 1945 emergence - spring of 1946	7' of top killed - summer of 1945 emergence - spring of 1946
L57-R43	2.8"	13'	Fall of 1945	1st incip. attack - 1939-40 these healed over - next attacks in 1944. fast growing - fall of 1945 emergence - spring of 1946	6' of top killed - summer of 1944 emergence - spring of 1945
L56-R41A	2.5"	14'	Summer of 1945	1st incip. attack - 1940 fast growing stage - fall of 1944 emergence - spring of 1945	7' of top killed summer of 1944 emergence - spring of 1945
L55-R38	3.5"	17'	Summer of 1946	1st incip. attack - 1940 fast growing stage - summer of 1946 emergence - spring of 1947	Light attack summer of 1945 but not sufficient to kill top some emergence in spring of 1946
L52-R37A	2.3"	12.5'	Summer of 1946	1st incip. attack - 1942 fast growing stage - summer of 1945 emergence - spring of 1946	6' of top killed summer of 1945 emergence - spring of 1946
L57 - R41	2.8"	13.5'	summer of 1946	1st incip. attack - 1942 fast growing stage - fall of 1945 emergence - spring of 1946	7' of top killed summer of 1945 emergence - spring of 1946

In the fall 20 trees were located which were dead and infested by the larvae of both weevil and the fast growing stage of the flathead. In addition, 7 more trees had been top-killed only. This loss amounted to over 25 percent of the surviving scopulorum trees in the block and was the heaviest for any year recorded. The depleted condition of the block as it appeared in August 1946 is shown by Figure 1.

Control measures were considered and the following decided upon:

1. Control of Cylindrocopturus. It was considered that this could be accomplished by thorough eradication of all infested material during the winter and by application in the spring of a DDT emulsion to the surviving trees to protect them from any weevils that might have escaped eradication or which might come in from outside pine areas.
2. Control of the incipient flathead infestation in the living trees. This would have to be purely experimental. No direct method of control is possible which will kill larvae in the living cambium without great injury to the tree. An indirect method proposed by Dr. Mirov was to stimulate the growth vigor of the trees by fertilizing the soil so that the trees would be in a condition to overcome the incipient larvae and contain their mines in the newly formed wood rings.

These two proposed methods, if successful, would overlap in their effects to a considerable extent. The DDT spray would serve not only to protect the trees from the weevil, but would also serve as a control for any adults of the flathead which might attempt to re-attack by ovipositing on the bark. The adults of this species of Melanophila feed for a period on the needles before they become sexually mature. During this period the adults move about over the needles, stems and limbs so that insecticides like DDT can be very effective against them.

Control for Cylindrocopturus eatoni

a. Eradication. During the fall of 1946 a search was made for all trees infested by overwintering larval broods, not only in the scopulorum block, but in other pine plantings, the arboretum and the nursery. Following is a list of the trees that were located:

Scopulorum progeny block:

Dead trees infested by weevil and fast growing flathead larvae	20
Topkilled trees infested by weevil and incipient	8

Arboretum

Dead tree - P. scopulorum infested by weevil larvae	1
" " P. montana " " " "	3

Nursery

Dead trees, 5-year-old stock, P. murrayanae, infested by weevil larvae	67
Dead trees, 5-year-old stock, P. murrayanae x P. banksiana, infested by weevil larvae	3
Total	102

All of these infested trees were cut and removed. Some of the material was selected for insectary rearing of adult weevils to be used in the 1947 experimental tests. The balance was hauled to the Lava Flat dump where it was burned.

b. Protective Spray. The following formulae was used:

DDT	1 pound
Xylene	3 pints
Triton	25 ounces
Water to make	12.6 pints

This formulae was applied to all scopulorum trees in the progeny block (excluding the Arizona trees) on May 21. A Bean power spray rig was used. Enough spray was used to wet both the needles and stems. To check effectiveness of the application samples of the sprayed stems and foliage were enclosed in a cage in the laboratory into which adults, both of the weevil and the flathead, were introduced at intervals during the summer. The spray deposit was effective in killing these adults until late summer.

No burning of foliage or other injurious effects of the spray were noted on any trees that were sprayed with the power rig. In the nursery a few small hybrids (P. murrayana x P. banksiana) were sprayed with a back pump to protect them from possible weevil attack. On these trees there was considerable burning of the needles which was probably due to an overdose of spray caused by the coarse nozzle that was used. None of these injured trees died, however, and all are making good growth in 1948.

A total of 49 scopulorum trees were sprayed in the progeny block, and 6 trees were reserved as checks. Figure 8 is a map of the block showing location of trees that were sprayed and fertilized, and of the 6 check trees. No trees were sprayed in the arboretum because eradication of the infested scopulorum tree, and the 3 P. montana trees was believed to have eliminated any infestation that might be a threat to the arboretum area during the 1947 season.

c. Results. Up to June 1948 it is apparent that control of Cylindrocopturus within the progeny block has been about 100 percent effective. No evidence of weevil activity was observed during the 1947 season. A check of all trees in May 1948 failed to reveal any evidence of overwintering weevil infestation.

However, two of the sprayed trees died during the summer of 1947 following application of the spray. Both of these trees were topkilled in 1946 and lost about half of their crowns when the infested tops were removed in February 1947. This injury apparently weakened the trees so that the incipient flathead larvae went into the fast growing stage and the trees soon died. There was no 1947/infestation whatever in these two trees, which would almost certainly have been the case if they had not been sprayed.

weevil

2. Control of Melanophila, californica.

a. Application of soil fertilizers to improve tree resistance.

Commercial fertilizers were applied to the soil under the trees at the rate of 1 pound of superphosphate and 3 pounds of ammonium sulphate to each tree. This application was made on March 4. In the scopulorum block the same 49 trees that were selected for spraying were fertilized; the same 6 check trees were left unfertilized.

In addition, 39 scopulorum trees and 7 P. banksiana trees were treated in the same manner in the arboretum. These trees in the arboretum were selected for treatment according to their condition. The trees that appeared to be the least vigorous were fertilized while the more vigorous trees were excluded. Table III gives a list of the line and row numbers of the trees that were treated. None of these arboretum trees were sprayed for weevil control.

b. Results. One of the first obvious effects of the fertilizer was stimulation of grass and Klamath weed growth around the trees. Enough rain occurred after March 4 to dissolve the fertilizer into the soil and the 1947 grass growth soon showed the effects. This stimulated growth of the ground cover was even more marked in the 1948 growth. Under some trees wild oats reached a height of 6 feet (see Figure 7).

It is still too early to measure the effect that the fertilizer may have on tree growth and incipient flathead larvae. This can be obtained later by a study of the 1947 and 1948 growth rings and of stem elongation. At the present time the treated trees appear to have a somewhat healthier appearance, judging from the foliage, than they did in 1947, but this also seems to be true of the checks.

Table III

List of treated *P. ponderosa* and *P. banksiana* in the Eddy Arboretum

1 pound Superphosphate, 3 pounds Ammonium Sulphate. Spread on ground under trees.

P. ponderosa treated March 4, 1947:

Row	Line	Row	Line
61	4	79	34
61	5	81	32
58	3	79	37
58	4	79	40
58	5	81	38
59	3	81	40
59	4	80	43
59	5	81	46
60	4	80	49
60	5	78	49
74	5	78	51
75	6	79	51
75	7	86	50
76	5	87	50
77	4	90	49
75	11	91	49
77	23	87	43
82	28	87	44
79	31	86	38
79	32		

P. banksiana treated March 31, 1947:

Row	Line
54	44
56	43
57	43
58	42
83	22
84	22
85	22

In the spring of 1948 it was found that 3 of the fertilized but unsprayed trees in the arboretum had died, and that one had been top-killed. These were

Line 5, Row 76, P. scopulorum - 9 feet of top killed by Cylindrocopturus

" 5 " 74, " - dead tree infested by fast-growing flathead larvae and Cylindrocopturus

" 4 " 58, P. banksiana - dead tree infested by flathead

" 3 " 58, " - " " " " "

These infested trees were all located at the north end of the Eddy Arboretum. The insect attacks developed during the summer of 1947. The source of the weevil infestation which attacked the scopulorum trees could not be determined but it is suspected that they came in from pine areas outside of plantings on Institute grounds.

SUMMARY

1. Geographical strains of P. ponderosa var. scopulorum grown from seed of strains that occur east of the Continental Divide and in Utah and Nevada have exhibited a slow growth behavior under conditions at the Institute of Forest Genetics.

2. Trees of these slow growing strains have been found to be highly susceptible to certain species of Pacific Coast insects which feed in the phloem and cambium areas. In the progeny test block high mortality resulting from attacks of the California pine flathead and the pine reproduction weevil developed soon after the first decade of growth was completed.

3. Trees grown from seed sources on the Coconino National Forest, Arizona, (also designated as variety scopulorum) have done much better under the same conditions. While the growth of the Arizona trees is not as vigorous as El Dorado strain of ponderosa pine, it is much better than that of the trees coming from South Dakota, Nebraska, Colorado, Utah, and Nevada.

4. The most striking difference between the Arizona trees and other strains of scopulorum trees growing here has been their apparent resistance to cambium feeding insects. So far no Arizona trees have been killed by insects in the scopulorum progeny block or in the arboretum, although the trees have been exposed to fairly strong insect populations which were killing nearby trees of the susceptible strains.

5. The pine reproduction weevil, which attacks the needles and the smooth bark of stem and branches, was controlled by spraying with a DDT water emulsion during late May 1947. Application of this spray to surviving trees in the scopulorum progeny block effectively controlled the weevil and abruptly checked tree mortality during the 1947 season.

6. The California pine flathead, which infests the living cambium over long periods in its slow-growing incipient stage, has no proven control remedy. Tests with commercial fertilizers, designed to control the flathead indirectly by stimulating the growth of scopulorum trees, were initiated in 1947. Results of these tests will not be available until another year or two have passed.

Figure 1

GENERAL VIEW OF SCOPULORUM PROGENY BLOCK FROM SOUTHWEST CORNER

JULY 1946

At time of planting trees were spaced 7½ feet apart. The thin area, occupying all but the left border and background of the picture, was planted with seed from localities east of the Continental Divide and other localities in Colorado, Utah, and Nevada. All trees from these seed sources have been characterized by slow growth and the mortality has been high.

Part of the stand of better trees in the background are from seed sources on the Coconino National Forest, Arizona. These were planted at the same time as the other scopulorum strains, but have made more rapid growth, and have suffered no mortality from insect attack.

Figure 2

FORM OF SLOW GROWING SCOPULORUM TREES

In the foreground are 3 living and 2 dead scopulorum pines of the Wyoming and South Dakota strains. Sparse foliage and dying limbs and twigs of the living trees indicate that incipient flathead larvae are working in the cambium. The full crowned trees in the background are the Arizona strain.

Figure 3

P. scopulorum - L52A, R41A. This tree was top-killed by Cylindrocopturus during the summer of 1945. (Hand points to height where top-killing begins). Weevils emerged from the infested top in the spring of 1946. Flathead larvae did not develop in the base and that part of the tree is still alive in June 1948. Spray application in 1947 protected the tree from attack during that season.

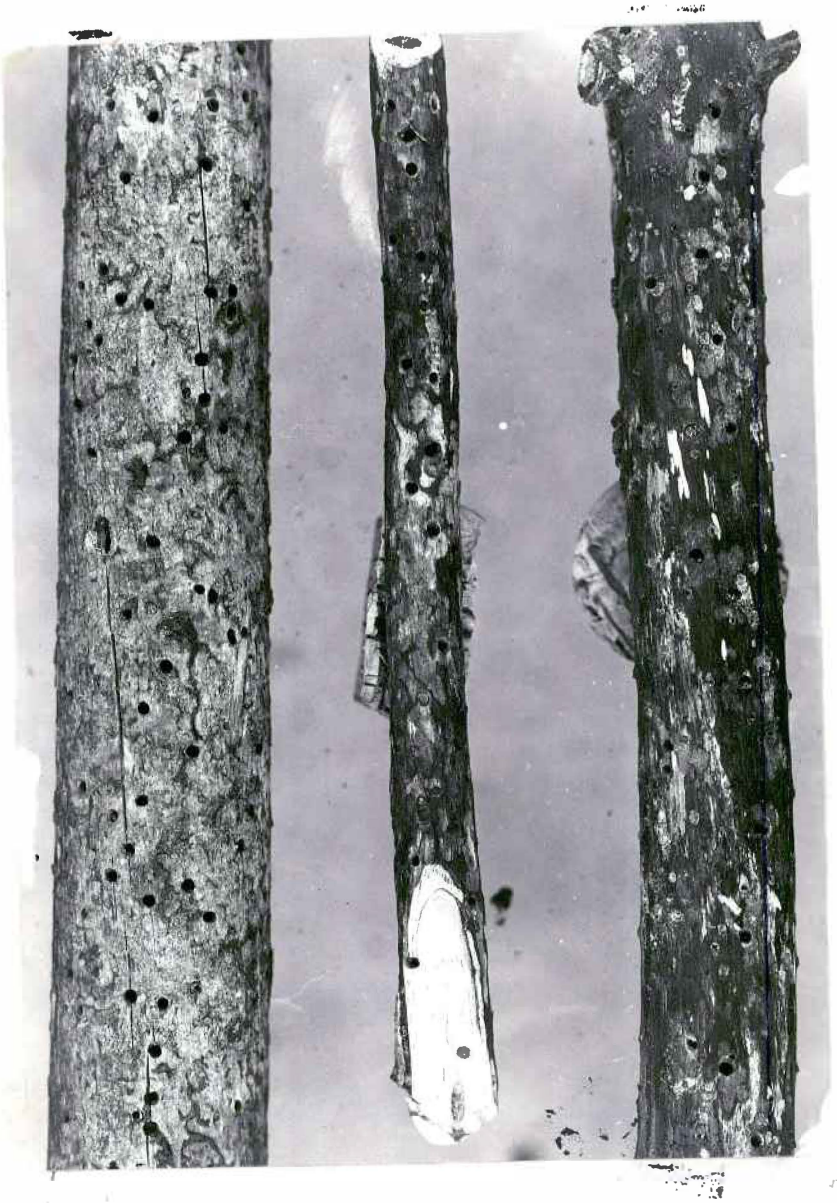

Figure 4

Holes made by mature weevil larvae when they enter the wood serve as exits for the new adults when they leave the tree. Long after the tree is dead these holes are certain evidence that it was infested by the weevil. The above sections, from the upper stem of a tree top-killed in 1944, show exit holes in the 1942, 1941, and 1940 internodes. The lower internodes were infested and killed by the pine flathead.

Figure 5

P. ponderosa - 1554, R36A. Seed from Teller Co., Colorado. Sown in 1929. Tree died during summer of 1945.
Cross-sections from main stem at base, 3 feet, 6 feet, and 7 feet.
Lower photo shows portions of 1943 and 1944 internodes on main stem.

The dark areas imbedded in the wood rings of cross-sections from base and at 3 feet are healed over scars made by incipient flathead larvae. Some of these scars in the outer two rings did not entirely heal over before the tree died.

The earliest of these incipient scars appear in the 1941 wood ring. Up to this year growth was slow but the rings are fairly strong and regular -- after 1941 the rings are suppressed and irregular.

A mine made by a Cylindrocopturus larvae cuts across the outer wood rings in the cross-section at 7'. These mines were numerous in the 1943-44 internodes. The weevil attacked and killed top of tree during the summer of 1945.

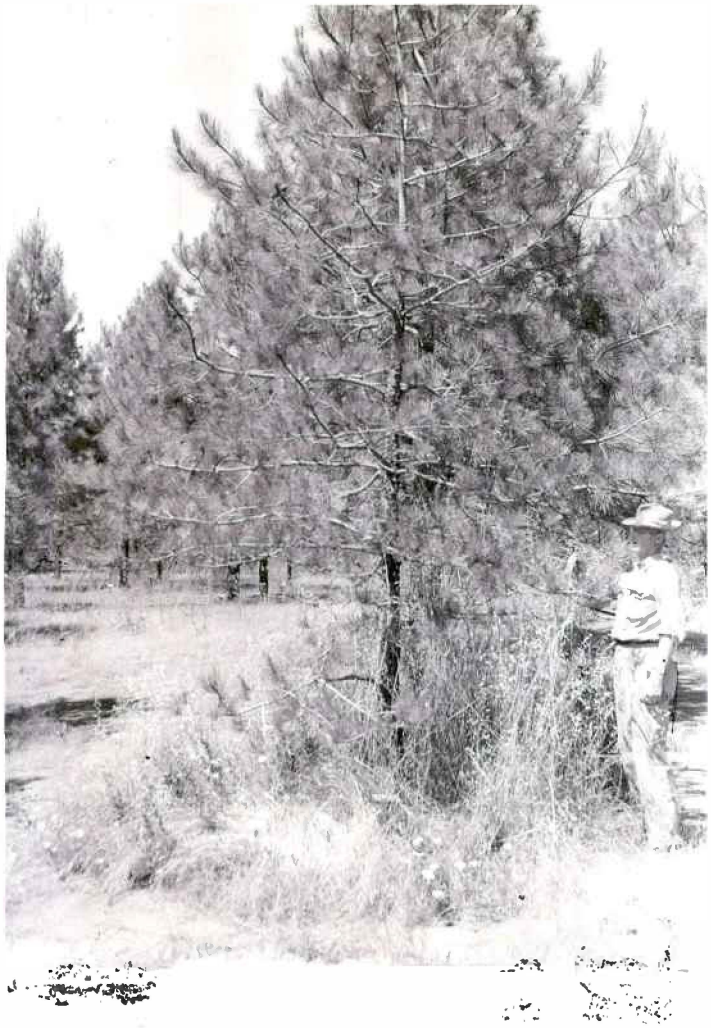

Figure 7

During the spring of 1947, 1 pound of superphosphate and 3 pounds of ammonium sulphate were spread under slow-growing scopulorum trees in the progeny block and arboretum to improve their condition and thus retard incipient flathead infestations. The first effect of the fertilizer was to stimulate growth of natural grasses around the treated trees. The 1948 growth of wild oats and Klamath weed around this fertilized scopulorum tree in the Eddy Arboretum far outstripped that in the surrounding area. Up to this time there was no visible stimulation of tree growth.

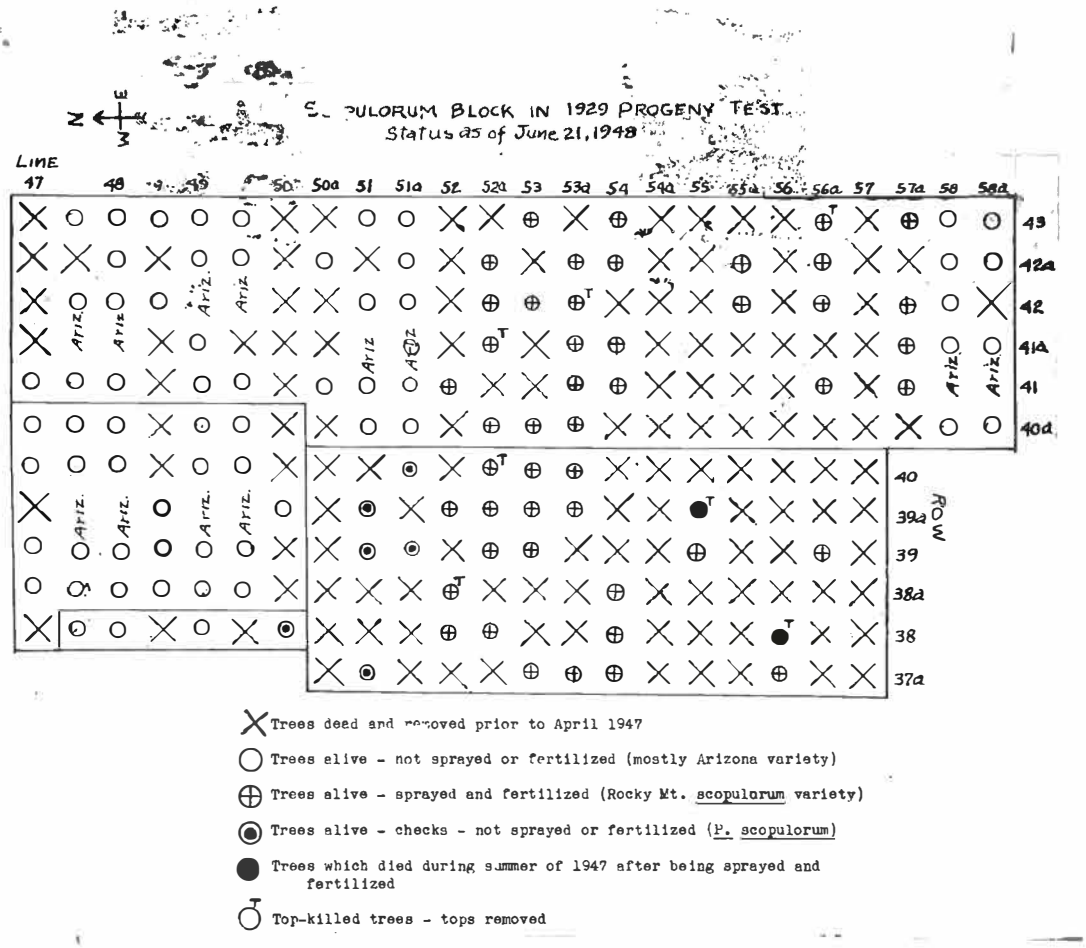

Figure 8

Chart of 1929 scopulorum progeny block showing location of trees still surviving as of June 21, 1948.